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Review Article

Endoscopic Third Ventriculostomy versus Ventriculoperitoneal Shunt in Hydrocephalus: Long-term Functional Outcomes, Failure Dynamics and Determinants of Success

Syeda Ayesha Bukhari[1], Mubeen Shahid[1], Ayesha Abbas[2], Muhammad Usama Khalid[3], Muhammad Zaki Ud Din[4], Hajra Azmat[5], Muhammad Sheraz[6], Qasim Zia[7*], Muhammad Salman Khan[7]

[1]Multan Medical & Dental College, Multan

[2]Bahawal Victoria Hospital, Bahawalpur

[3,4,7]Multan Medical & Dental College, Multan

[5]Islam Medical and Dental College, Gujranwala

[6]Nishtar Medical University, Multan

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***Corresponding author:** Qasim Zia, Multan Medical & Dental College, Multan

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ABSTRACT

Hydrocephalus represents a chronic neurological condition requiring effective and durable cerebrospinal fluid (CSF) diversion. Ventriculoperitoneal shunting (VPS) has traditionally been regarded as the gold standard; however, endoscopic third ventriculostomy (ETV) has emerged as a physiologically restorative alternative, particularly in obstructive hydrocephalus. This manuscript provides a comprehensive evaluation of long-term functional outcomes, complication profiles, and temporal failure patterns associated with both modalities. Evidence indicates that VPS offers superior early clinical success but is associated with cumulative failure and lifelong device dependency. Conversely, ETV demonstrates higher early failure rates but confers improved long-term durability, reduced infection risk, and enhanced quality of life in appropriately selected patients. The evolving paradigm emphasizes individualized, etiology-driven treatment strategies supported by predictive tools such as the ETV Success Score (ETVSS).

INTRODUCTION

Hydrocephalus is a multifactorial disorder characterized by abnormal accumulation of CSF within the ventricular system, resulting in ventricular enlargement and elevated intracranial pressure (ICP).[1,2] The condition spans all age groups and remains a significant contributor to neurological morbidity worldwide, with disproportionate burden in resource-limited settings.[3,4] Despite decades of clinical experience, the optimal approach to CSF diversion continues to evolve.

VPS has long been the cornerstone of treatment due to its versatility and immediate efficacy across diverse etiologies. However, its reliance on an implanted system predisposes patients to a spectrum of complications, including infection, obstruction, and mechanical failure, often necessitating repeated surgical interventions.[5-7] In contrast, ETV offers a device-independent solution by re-establishing physiological CSF pathways, thereby addressing the underlying pathophysiology in obstructive hydrocephalus.[8,9]

The contemporary discourse has shifted toward evaluating not only surgical success but also long-term functional independence, neurocognitive outcomes, and healthcare burden. These considerations are particularly relevant in the context of chronic disease management.

Global Burden and Health System Implications

Hydrocephalus imposes a substantial global health burden, with estimates suggesting millions of affected individuals worldwide and significant disparities in access to neurosurgical care.[4,10] In low-resource settings, the high cost and maintenance demands of VPS systems pose considerable challenges, including limited access to revision surgeries and increased infection rates.

ETV has gained prominence in such environments due to its reduced dependence on hardware and lower long-term maintenance requirements. Studies from sub-Saharan Africa and South Asia have demonstrated the feasibility and cost-effectiveness of ETV, particularly when combined with choroid plexus cauterization (ETV+CPC) in pediatric populations.[20,29] These findings underscore the importance of context-specific treatment strategies.

CSF Hydrodynamics and Mechanistic Differences

Understanding the hydrodynamic principles underlying both procedures is essential for appreciating their long-term outcomes. VPS alters CSF dynamics by creating an extracranial drainage pathway, often leading to non-physiological pressure gradients and complications such as overdrainage and slit ventricle syndrome. [25,26]

In contrast, ETV restores near-normal intracranial CSF circulation by bypassing obstructed pathways while preserving natural absorption mechanisms. This physiological approach minimizes pressure fluctuations and may contribute to improved long-term neurological stability.[11,19] However, its success is contingent upon intact subarachnoid absorption, limiting its applicability in communicating hydrocephalus.

Comparative Analysis of Early Outcomes

The early postoperative period is characterized by distinct outcome profiles for VPS and ETV. VPS demonstrates high immediate efficacy, with rapid normalization of intracranial pressure and symptom resolution in the majority of patients.[12,13] This reliability is particularly advantageous in acute settings and in patients with complex or mixed etiologies.

ETV, although effective, is associated with a higher rate of early failure, often due to stoma closure or suboptimal CSF flow dynamics.[14,21] Randomized trials and meta-analyses consistently demonstrate a modest early advantage

for VPS in terms of clinical success.[15,16] However, early outcomes must be interpreted within the broader context of long-term performance.

Long-term Functional Outcomes and Neurodevelopment

Long-term functional outcomes increasingly favor ETV, particularly in terms of independence from medical devices and reduced healthcare utilization. Patients who achieve successful ETV are less likely to require repeated hospital admissions and demonstrate improved psychosocial functioning.[17,18]

Neurodevelopmental outcomes are of particular importance in pediatric populations. Evidence suggests that stable intracranial pressure dynamics achieved through ETV may support more favorable cognitive development compared to the intermittent pressure fluctuations associated with shunt malfunction.[19,20] Nevertheless, heterogeneity in study designs and patient populations necessitates cautious interpretation.

Failure Dynamics and Survival Analysis

A defining feature of the ETV versus VPS comparison lies in their contrasting failure dynamics. ETV failure is predominantly an early phenomenon, occurring within the first three months postoperatively. Once this critical period is surpassed, long-term patency rates remain relatively stable.[21,31]

In contrast, VPS is characterized by a persistent risk of failure over time. Shunt survival rates decline progressively, with approximately 40% failing within the first year and up to 50% within two years.[22-24] This cumulative risk reflects the mechanical and biological vulnerabilities inherent in implanted systems.

Survival analysis studies highlight that while VPS outperforms ETV in the short term, ETV demonstrates superior durability beyond the initial postoperative period. This temporal divergence has significant implications for lifelong patient management.

Complications and Risk Stratification

The complication profiles of VPS and ETV differ not only in type but also in clinical impact. VPS-related complications, including infection and mechanical failure, contribute significantly to morbidity and healthcare costs.[25-28] Infection remains a major concern, often necessitating complete system removal and prolonged antibiotic therapy.

ETV complications are primarily procedural and include hemorrhage, neurological injury, and CSF leakage.[27] Although less frequent in the long term, the potential for sudden late failure due to stoma closure necessitates ongoing surveillance.

Risk stratification tools, such as the ETVSS, play a crucial role in optimizing outcomes by identifying patients most likely to benefit from ETV.[31] Incorporation of such predictive models into clinical practice enhances decision-making and reduces failure rates.

Special Considerations and Emerging Techniques

Certain clinical scenarios warrant tailored approaches. In post-hemorrhagic and infectious hydrocephalus, impaired CSF absorption often limits the effectiveness of ETV, making VPS the preferred option.[30] Conversely, in cases of aqueductal stenosis or posterior fossa tumors, ETV offers excellent outcomes.

Emerging techniques, including ETV combined with choroid plexus cauterization, have shown promise in improving success rates in infants, traditionally considered poor candidates for ETV.[20,29] Advances in neuroendoscopic technology and imaging guidance continue to refine procedural safety and efficacy.

Economic and Ethical Considerations

The economic implications of hydrocephalus management are substantial. While VPS is associated with lower initial costs, the cumulative expense of revisions, hospitalizations, and complications significantly increases long-term healthcare burden.[36] ETV, despite higher upfront costs, demonstrates superior cost-effectiveness over time.

Ethically, the choice of intervention must balance immediate clinical needs with long-term quality of life. In resource-limited settings, the sustainability of treatment becomes a critical factor, further supporting the role of ETV where feasible.

DISCUSSION

The comparison between ETV and VPS underscores the importance of individualized, evidence-based decision-making in neurosurgery. VPS remains indispensable due to its universal applicability and reliability in acute settings. However, its long-term limitations necessitate consideration of alternative strategies.

ETV represents a paradigm shift toward physiological restoration of CSF dynamics, offering durable outcomes and reduced complication burden in selected patients. The key challenge lies in accurate patient selection, guided by clinical, radiological, and predictive factors.

Importantly, the apparent equivalence in overall success rates between the two modalities obscures fundamentally different risk profiles. ETV concentrates risk in the early postoperative period, whereas VPS distributes risk over a lifetime. Recognizing this distinction is essential for informed consent and long-term management planning.

Future research should focus on integrating advanced imaging biomarkers, refining predictive models, and conducting long-term prospective studies to better understand functional and neurocognitive outcomes.

CONCLUSION

ETV and VPS are complementary rather than competing modalities in the management of hydrocephalus. VPS provides reliable early outcomes and broad applicability, while ETV offers superior long-term durability and quality of life benefits in appropriately selected patients. The optimal approach requires a nuanced understanding of disease pathophysiology, patient characteristics, and temporal outcome patterns.

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